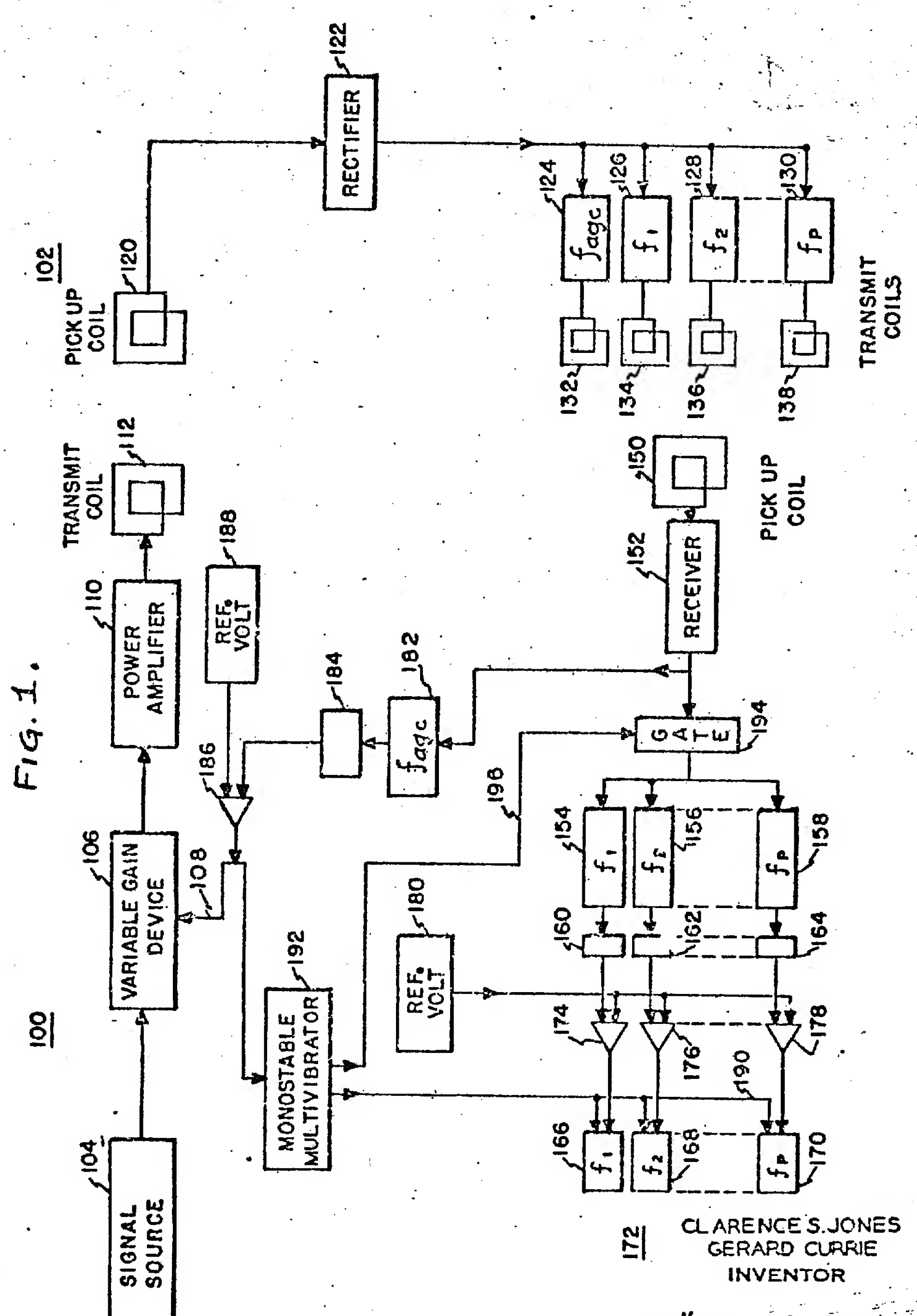
Oct. 27, 1959 C. S. JONES ET AL 2,910,579

SIGNALLING SYSTEM

Filed July 10, 1958 2 Sheets-Sheet 1



CLARENCE S. JONES
GERARD CURRIE
INVENTOR

BY Harry [signature]
ATTORNEY

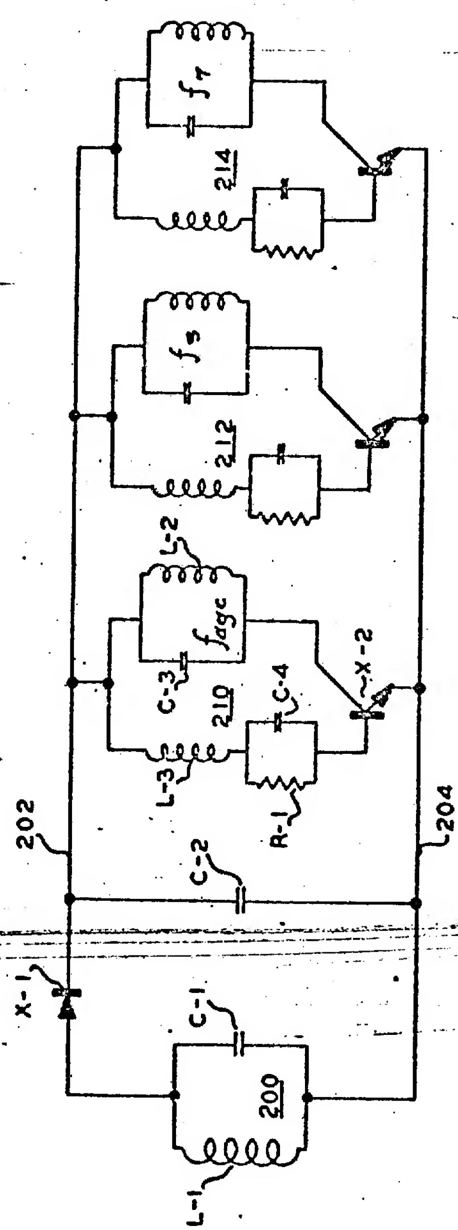


FIG. 2a

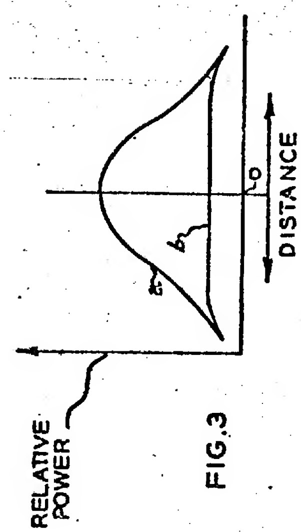


FIG.3

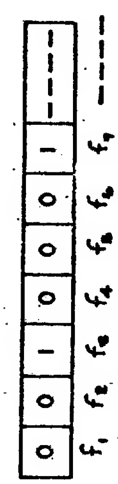


FIG 2b

CLARENCE S. JONES
GERARD CURRIE
INVENTOR

BY Harvey J. Lambert
ATTORNEY

United States Patent Office

2,910,579

Patented Oct. 27, 1959

2,910,579

SIGNALLING SYSTEM

Clarence S. Jones, Los Altos, and Gerard Currie, Santa Clara, Calif.

Application July 10, 1958, Serial No. 747,669

20 Claims. (Cl. 250—2)

This invention relates to electrical signalling systems, and more particularly to apparatus for identifying the location of a first object with respect to one or more of a plurality of second objects. The invention may be utilized for a variety of different purposes, a number of which will be mentioned below.

In the transportation and materials handling fields in general, and particularly in the efficient operation of a railroad, it often becomes desirable to know information such as where each train is at any time, or with what velocity the train is moving, or where individual railroad cars are located. Sometimes it is of great advantage to determine the location of goods or materials carried on railroad vehicles, trucks or conveyers.

A considerable saving may often be effected if a central agency is apprised, at all times, of selected portions of the above information, since the railroad and trucking businesses involve long distances covering a large territory, usually without communication equipment readily available. For example, scheduling of trains may be considerably simplified by remotely observing the density of traffic at crowded switching points. Information regarding the location and identity of available railroad vehicles stored on sidings is immensely useful in determining the type and amount of freight space available at any of the loading centers. Information on the instantaneous location of particular goods, such as raw materials or cattle shipped across country on separate trains or trucks may help the recipient to make necessary arrangements for unloading, storing or the like.

Referring now more specifically to the railroad business, it has heretofore been suggested that radio links be established between each engine or each train and a central agency in order that the operators be able to inform the central agency of their location. While such systems have been quite useful, their effectiveness has been limited by the fact that each train operator must be relied upon always to furnish accurate information with regard to the location of his train. Additionally, the location of selected special purpose equipment, such as refrigerator cars or heavy-duty freight cars, may require further radio links situated proximate to such loading or storage centers and be operated by railroad yard personnel, since the train operator usually does not have the means or responsibility to ascertain or keep track of the identity of the individual cars on his train.

The need for an automatic signalling system for furnishing accurate information with regard to train or truck location or goods identification to a central agency has long been recognized, and various systems have been proposed. As far as is known, none have been very successful, except the system disclosed in application Serial Number 715,899 filed February 18, 1958, by Clarence S. Jones for "Signalling System," which application was assigned to the same assignee as the present invention.

The specific system disclosed in detail in the Jones application may be said to comprise an interrogator-responder system, utilizing an interrogator apparatus to

apply radio frequency energy to a transmit coil carried on a movable device, such as a railroad vehicle. In the Jones application, successive bursts of radio frequency energy are transmitted on different frequencies, which are cyclically repeated. As the vehicle carrying the transmit coil moves sufficiently close to any one of a plurality of passive response blocks distributed along the right-of-way, certain of the radio frequency bursts operate resonant circuits within the response block to furnish power to operate a small responder oscillator, which transmits a return signal on a further radio frequency. By selective use of different tuned circuits in different response blocks the responder oscillator will provide a series pulse code signal for reception by a receiver associated with the interrogator and used to identify each response block. As well as using the interrogator on a vehicle to determine vehicle position with respect to a plurality of fixed locations, the Jones system contemplates locating the interrogator at a fixed location to identify objects passing by which are provided with suitable passive response blocks and which pass within the signal field of the interrogator.

The basic system disclosed in the Jones application offers an extreme advantage over prior systems in that it uses purely passive automatic response block units without being inaccurate or unreliable, so that numerous remote stations or locations may be provided with response means without attendant provision of electric batteries or wired power sources. While passive response units have heretofore been provided elsewhere, all of these, of which we are aware, required precise physical alignment and were adversely affected by various environmental factors.

While the invention of application Serial Number 715,899 admirably accomplishes its purposes, and while it is ideally suited for a wide variety of applications, certain applications benefit from modification of the Jones system. For example, the specific interrogator disclosed in detail in the Jones system transmits a series of radio frequency signal bursts, each of a different frequency, with a burst of radio frequency energy of a further frequency interposed between each code signal for automatic gain control purposes. If a large number of differently coded response blocks are to be used, so that the system may employ a relatively large number of binary digits, a large number of different interrogator frequencies must be transmitted. This requirement may be troublesome when the system is applied to the identification of very rapidly moving objects or to the identification of the location of an object which moves rapidly with respect to a plurality of fixed locations.

In order to allow the use of economical circuitry and still preserve system reliability, the time length of each radio frequency signal burst must be maintained at or above a minimum value. In the case of rapidly moving bodies, the interrogator transmit coil and response pick-up coil may remain sufficiently close to a response block to interrogate the block only during a short period of time, so that an insufficient number of interrogator frequencies can be transmitted if each frequency is alloted its required duration. The present invention is in some respects an improvement over the Jones invention in that it overcomes the described limitation by interrogating a plurality of digits simultaneously.

In certain other applications signalling systems of this nature may be used to transmit data relating to the position of a movable object with respect to successive fixed locations. Sometimes it is desirable to be able to determine the rate at which an object is moving by noting the rate at which it passes by a number of fixed stations. If a precise velocity determination is to be made at a given instant, rather than a mere average velocity determination, it may be understood that vehicle location must

be noted at different locations which are very close to each other. If responders are located very close to each other, and if vehicle speeds become great enough, it is sometimes absolutely necessary that all identification or code digits be determined simultaneously.

It is therefore one object of my invention to provide an improved signalling system for automatically identifying, locating or numbering a plurality of objects.

It is another object of my invention to provide an improved signalling system of the type in which a plurality of digits are interrogated simultaneously.

It is still another object of my invention to provide an improved signalling system for interrogating a plurality of digits simultaneously utilizing a simplified interrogator.

It is a further object of my invention to provide an improved signalling system wherein a simplified interrogator unit interrogates a response block with a burst of electromagnetic energy of a single frequency and wherein the response block responds thereto with bursts of electromagnetic energy of a selected plurality of different frequencies corresponding to identification digits in which the signal provided by the response block is capable of uniquely identifying one of a large number of response blocks.

It is a further object of this invention to provide an improved signalling system wherein the high power interrogator signal is of a single frequency and the low power responder signals comprise a plurality of different frequencies to minimize interference effects.

It is a further object of my invention to provide an improved signalling system for interrogating a plurality of digits simultaneously wherein the interrogator transmit coils and the responder pick-up coils may be sharply tuned so as to allow greater sensitivity and accuracy.

It is a still further object of my invention to provide an improved signalling system which is reliable in operation, simple in design and economical in construction.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

In accordance with one embodiment of the invention, an interrogator unit, also called the interrogator, is mounted upon a moving vehicle whose location is to be determined at fixed intervals. The interrogator has a transmitter channel which originates and radiates a radio frequency interrogator signal of a single frequency. A number of response blocks, also referred to as responders, may be located at various intervals along a railroad track or roadbed over which the vehicle passes. In case of railroad tracks, the preferred position of each responder is the top or inside of a selected track tie.

The location of and the distance between individual response blocks is largely a matter of choice and depends where and how often the location of the vehicle is desired. As will be explained below, the number of response blocks which may be utilized throughout a whole railroad network are limited, at least to some extent, by the number of digits with which the signalling system is provided.

As stated above, the respective position of the interrogator and responders may be exchanged so that the interrogator unit is fixed and each of the moving vehicles carries a response block. Such an arrangement is preferred when goods are moved by conveyor or the like over or past the interrogator, or when freight cars are to be classified upon entering or leaving a switchyard.

When the interrogator is located near or directly above a response block, the pick-up coil of the responder receives the interrogator signal and rectifies the same to provide a response-actuating signal therefrom. The response-actuating signal is utilized to power a selected plurality of responder oscillators which simultaneously provide a plurality of selected radio frequency responder signals of different frequencies which identify a particular responder. The presence or absence of a particular responder signal provides a convenient binary code for identifying responders uniquely. Each oscillator corresponds to a digit and since a particular responder is provided with a selected number of oscillators of predetermined frequencies, the interrogator signal, after rectification, interrogates all the digits simultaneously. The response-actuating signal is the sole power required to operate the response oscillator, so that no batteries or wired power sources are necessary.

The selected plurality of responder signals radiated by the response oscillators are coupled electromagnetically to and are amplified by an interrogator receiver channel, which may be physically located with the interrogator transmitter channel. In some applications, it may be considered advantageous to utilize a particular responder signal to provide a control voltage for automatic gain control of the transmitter channel. The signal received and amplified by the receive channel is actually a composite response signal and may be applied to a radio frequency-discriminator device which has a separate output channel for each frequency included in the selected plurality of responder signals comprising the composite response signal. Each discriminator output channel is selectively responsive to a predetermined one of the different responder signals. The composite responder signal, being a mixture of selected responder signals, is thereby unscrambled or separated into individual responder signals to provide a signal indicative of the presence or absence of a responder signal. This signal may be suitably rectified to provide an output voltage on each channel associated with a selected responder signal. The presence or absence of an output voltage on a channel may be utilized to set the stages of a code register as either a "one" or a "zero" for providing a binary number which determines uniquely the particular response block being interrogated.

The digital code set into the code register may be transmitted to a central agency by any of the many well known data link systems. Since the central agency in a railroad signalling system of the kind here described usually desires information from a large number of railroad trains, and since it might be uneconomical to provide separate data link receivers for each interrogator, it often will be convenient to add an identification register to the code register. An identification register may be provided with each interrogator, so that signals which identify the interrogator are sent to the central agency to specify which interrogator is "reporting" to the central agency. The addition of such an identification register increases the number of bits which must be transmitted by the data link system by the number of bits necessary to identify a particular interrogator unit. The additional register, however, does not complicate the interrogator itself since it is not a part of the interrogator and only comes into operation in connection with a data link system.

No electromagnetic interference problem is encountered in the transmission of high power electromagnetic radiation from the interrogator to the responder since the interrogator signal is of a single frequency. From this point of view, the present invention presents an additional improvement over the Jones system in that all interference problems are transferred from the high power level of interrogation to the low power level of responding.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is a schematic electrical block diagram illustrating one embodiment of the signalling system of this invention as it might be used in connection with a railroad data transmission system;

Fig. 2*a* is an electrical schematic diagram of an embodiment of a coded passive responder which may be utilized with the signalling system of this invention;

Fig. 2*b* is a binary code diagram of the responder em-

bodiments of Fig. 2a and is included to aid in the explanation of the coding technique utilized in the responders: and

Fig. 3 is a graphical illustraton useful in understanding the operation of the automatic gain control feature of this invention.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which a preferred embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of my invention.

Referring now to the drawings, and particularly to Fig. 1 thereof, there is shown an embodiment of a signalling system in accordance with this invention. The signalling system essentially comprises an interrogator, 100 for providing and radiating an interrogator signal in the form of an electromagnetic wave of a single frequency and for receiving and decoding an electromagnetic wave in the form of a selected plurality of responder signals, and a responder 102 for developing and radiating the selected plurality of responder signals upon receipt of the interrogator signal. As will be described hereinafter in more detail, interrogator 100 is capable of relative motion with respect to responder 102 and unless within a selected minimum distance therefrom, may not electromagnetically couple sufficiently closely with responder 102 to actuate or to receive the selected plurality of responder signals.

The portion of interrogator 100 which provides and radiates the interrogator signal is also referred to as the interrogator transmitter means, and may include a conventional radio frequency oscillator means such as signal source 104 having a sinusoidal output voltage of a predetermined amplitude and frequency. The output of signal source 104 is referred to as the interrogator signal and is of a single frequency. The interrogator signal may be applied to a variable gain device 106 which may include automatic gain control means responsive to an automatic gain control difference voltage appearing on the conductor 108. Device 106 may be utilized to control the amplitude of the interrogator signal in accordance with the automatic gain control difference voltage. The purpose of providing automatic gain control for the signalling system and the method of developing the automatic gain control difference voltage will be explained below in connection with Fig. 3. Variable gain device 106 may take any of many forms well-known to those skilled in the art, and which are sometimes referred to as variable gain attenuators or variable gain amplifiers.

The output signal of variable gain device 106, designated as the amplitude controlled interrogator signal, may be suitably amplified, if desired, by an amplifying means such as a conventional power amplifier 110 to increase the power level of the interrogator signal sufficiently to cause a radiator such as transmit coil 112 to radiate the interrogator signal as an electromagnetic wave of desired strength. Transmit coil 112 is excited by the interrogator signal and may comprise, for example, a parallel tuned inductance-capacitance network resonant at the interrogator signal frequency. Since transmit coil 112 radiates but a single frequency, it is advantageous, from a power transfer point of view, to utilize a sharply tuned coil. It is of course clear to those skilled in the art that the position of variable gain device 106 need not be intermediate between signal source 104 and amplifier 110 but may be inserted instead between amplifier 110 and coil 112. The advantage of the relative position of device 106 as shown in Fig. 1 is that control of low power signals may be more convenient.

The combination of signal source 104, variable gain device 106 which is controlled by the voltage appearing on lead 108, amplifying means 110, and transmit coil 112 provides an interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for generating and transmitting an amplitude controlled electromagnetic interrogator signal of a single frequency.

A responder pick-up means such as pick-up coil 120 may provide the receiver element of responder 102 for receiving the electromagnetic interrogator signal when electromagnetically coupled to transmit coil 112. Pick-up coil 120 may comprise a tuned circuit resonant at the interrogator signal frequency radiated by transmit coil 112 and may be sharply tuned to effect an efficient transfer of power. As is well known to those skilled in the art, a tuned circuit such as pick-up coil 120 behaves like a receiving antenna and may provide a pick-up means for receiving the electromagnetic interrogator signal.

The signal induced into pick-up coil 120 may be impressed on a rectifying means such as conventional rectifier 122 which includes a filter to convert the induced alternating current interrogator signal to a direct current voltage to be referred to as the response-actuating voltage. As will become clearer hereinafter, the response-actuating voltage is the sole power furnished to the response-actuating portion of the responder 102.

The response-actuating voltage is utilized to power an oscillator means which may include a plurality of responder signal oscillators, only four of which are shown and respectively designated by reference character 124, 126, 128 and 130. Each responder signal oscillator develops simultaneously a responder signal of a different frequency in response to the response-actuating voltage respectively designated f_{agc}, f_1, f_2, and f_3. As will become more evident from the description below, the actual number of responder signal oscillators required for a signalling system depends on the desired number of different responders to be interrogated. As will be described in detail in connection with Fig. 2a, responder oscillators 126, 128 and 130 are digit or code oscillators and provide a selected plurality of code responder signals which identify a particular responder uniquely. If the maximum number of different code oscillators utilized by a signalling system is designated by the letter p, a different selected plurality varying in number from 1 to p of these code oscillators are included in each responder. Responder signal oscillator 124, also referred to as the automatic gain control oscillator, does not ordinarily participate in the identification process but rather provides a responder signal utilized for automatic gain control purposes.

Each responder signal may be impressed upon an associated responder transmit means such as transmit coils respectively designated by the reference characters 132, 134, 136 and 138. Transmit coils 132, 134, 136 and 138 each comprise a suitable radiation element for radiating one of the responder signals as electromagnetic radiation towards the receiver channel of interrogator 100. A more detailed description of responder 102 is offered in connection with Fig. 2, wherein the responder transmit coils comprise respectively the tank circuits of the associated responder signal oscillators.

In this manner, responder signal oscillators 124, 126, 128 and 130 with their respective associated transmit coils provide an oscillator means responsive to the response-actuating voltage and operate to develop and radiate a selected plurality of responder signals of different frequencies simultaneously.

The portion of interrogator 100 which receives and decodes the responder signals may be termed the interrogator receiver means and includes a pick-up means such as pick-up coil 150. Pick-up coil 150 provides the

receiver element for receiving the electromagnetic signal from responder 102 when electromagnetically coupled to transmit coils 132, 134, 136 and 138 and may comprise a tuned circuit relatively broadly tuned to receive any and all of the responder signals. The term pick-up means is intended to include one or more tuned circuits.

The signal developed by coil 150 is really a combination of all the responder signals and is therefore termed the composite responder signal. The composite responder signal may be applied to an amplifying means such as a conventional receiver 152 so that the composite responder signal will be amplified to a desired power level. In some systems of the type here described, it may be desirable to lower the frequency of the received composite responder signal. This may be accomplished by utilizing a conventional beat frequency oscillator as part of or in conjunction with receiver 152 as is well known to those skilled in the art. The output from the beat frequency receiver would be a reduced frequency composite responder signal. The main advantage of a low frequency is that audio instead of radio frequency filters may be utilized to separate the reduced frequency composite responder signal. It can be seen, therefore, that the combination of pick-up coil 150 and receiver 152 provide an interrogator receiver means which is associated with the interrogator transmitter means and which is responsive to the selected plurality of responder signals and operative to develop a composite responder signal.

The received composite responder signal may then be separated or unscrambled or decoded into individual responder signals by a plurality of narrow band-pass frequency filters of which three are shown and designated respectively by reference characters 154, 156 and 158. It is, of course, evident that for each responder signal which the system may utilize there must be an associated band-pass filter so that a total of p filters are required. The designation shown inside the rectangles designating the filters in Fig. 1 indicates the center frequency of its pass band. The plurality of filters as such may be referred to as a responder signal filter means since it suppresses from any one filter output all responder signals except a selected one which it passes.

Each filter such as 154 may be of conventional design and may comprise either a parallel-tuned or series-tuned inductance-capacitance passive network, or in certain instances it may be desirable to utilize an active filter of the well-known type comprised of a feedback amplifier containing a twin-T RC network in its feedback path. Each of the tuned circuits is resonant at a different one of the responder signals, and operative to pass only the responder signal at the resonant frequency of the tuned circuit. The plurality of filters therefore may be seen to comprise a responder signal filter means responsive to the composite responder signal and operative to derive a separate coding signal for each one of the selected plurality of responder signals. Of course, if a beat frequency receiver is used, then the filter means would comprise audio filters.

The output from each of the filters is, of course, an alternating current signal (coding signal) of the frequency of the particular responder signal. It is sometimes desirable to rectify each of these alternating current voltages to derive therefrom direct current voltages referred to as coding voltages. For this purpose, a rectifying means such as the plurality of associated rectifiers designated respectively by the reference characters 160, 162 and 164 may be utilized. In this manner the individual associated rectifiers provide a detector means responsive to each of said coding signals and operative to develop coding voltages.

The coding voltages may be utilized in a variety of ways and represent, as the name suggests, a binary code indicating which ones of the p different responder oscillators are present in a particular response block. It should now be obvious to those skilled in the art that the number of responder signal oscillators, such as the one designated by reference character 134, determines how many different response blocks or responders may be uniquely identified. For example, if a particular interrogator receiver means is equipped to uncode or separate three code responder signals from the composite responder signal, a maximum of three responder signal code oscillators may be utilized and only eight different combinations of coding voltages can be developed. Consequently only eight different responders can be uniquely identified. If an interrogator receiver means can separate or filter four different code responder signals, then a maximum of four responder signal oscillators may be utilized and sixteen responders may be uniquely identified. As is well known, if the number of response blocks to be identified is X, the maximum number p of code responder signal oscillators necessary to provide unique identification is given by the expression $X=2^p$ where p is, of course, an integer. If 8,000 responders are to be uniquely identified, a maximum of 13 different code responder signal oscillators are required and the receiver channel of interrogator 100 must be capable of being selectively responsive to 13 code responder signals. This number of course, does not include the automatic gain control responder signal which requires its own associated filter.

The coding voltages from the rectifiers associated with the responder signal filter means, being a binary code, may be directly applied to the binary stages such as the ones designated by refeernce characters 166, 168, and 170 of a code register 172. Obviously, the number of stages required for register 172 is the same as the number of code responder signals which the interrogator receiver means can decode, each stage being associated with a different one of the possible code responder signal oscillator which may be utilized. Each stage of register 172 may be set by either the occurrence or the absence of a coding voltage from an associated rectifier.

It has been found that the reliability of the signalling system of this invention may be improved by applying the coding or digital voltages from detectors such as 160, 162 and 164 to the input circuits of a plurality of associated comparing means, such as the conventional differential amplifiers 174, 176 and 178, instead of directly to the respective stages of code register 172. In this manner, the coding or digital voltages may first be compared with a reference voltage of a selected amplitude from a source 180 to make certain that the coding voltages have originated from code responder signals instead of merely being noise or stray pick-up. Unless the magnitude of a coding voltage from a given detector is above a selected minimum level, indicating the presence of a responder signal and a desired degree of electromagnetic coupling between interrogator 100 and responder 102, its associated differential amplifier will not provide a coding voltage difference signal, and the stages of register 172 will not be set erroneously by noise or stray pick up signals. Reference voltage source 180 may, of course, include an adjustment means such as a potentiometer to provide an adjustable reference voltage so that the level at which a code responder signal provides a coding voltage difference signal may be adjusted. The combination of the associated differential amplifiers 174, 176 and 178 and reference voltage source 180 therefore provides a comparing means responsive to each of the coding voltages for comparing the magnitude of each of the coding voltages with a reference voltage and is operative to derive coding voltage difference signals.

Since interrogator 100 and responder 102 are capable of relative motion with respect to one another, the electromagnetic coupling between interrogator transmit coil 112 and responder pick-up coil 120 may increase from a small value during the approach to a maximum value when the relative distance therebetween is a minimum, and thereafter may decrease again as the two objects move apart in

opposite direction. The same is, of course, true of the electromagnetic coupling between responder transmit coils 132, 134, 136 and 138 and interrogator pick-up coil 150. If the electromagnetic radiation from transmit coil 112 remains constant, the power level of the response-actuating voltage developed by rectifier 122 will change with the electromagnetic coupling. The power level of the individual responder signals radiated by pick-up coils, such as 132, 134, 136 and 138, depends on the power level of the response-actuating voltage and consequently varies also with the degree of electromagnetic coupling between transmit coil 112 and pick-up coil 120. Additionally, the power level of the composite responder signal developed by pick-up coil 150 will depend on the power level of the individual responder signal and the electromagnetic coupling between transmit coils 132 134, 136 and 138 and pick-up coil 150 which, as explained above, changes as the relative distance between interrogator 100 and responder 102 changes.

It is therefore easily seen that during the time interrogator 100 and responder 102 are in close proximity to one another, the power level of the composite responder signal developed by pick-up coil undergoes a substantial change. This change of power level, unless corrected or compensated for, is directly reflected upon the magnitude of the coding voltages, and it is impossible to provide a reference voltage level for the comparing means, such as differential amplifier 174, to assure that a voltage from rectifier 160 is due to a code responder signal. The power level of the individual code responder signal developed at the output of the responder signal filter means, such as filter 154, is depicted by curve *a*, Fig. 3. Curve *a*, Fig. 3, is a plot of the relative power level of a code responder signal as passed by a filter of the responder signal filter means plotted against distance between interrogator 100 and responders 102.

By providing automatic gain control, the power applied to amplifier 110 may be controlled so that the output of each filter of the responder signal filter means remains nearly constant during the time interrogator 100 and responder 102 are in close proximity. Curve *b*, Fig. 3, depicts the power level of the responder signal filter means when automatic gain control is provided and shows a substantially flat portion which corresponds to a selected minimum distance. One cause of power level variation, not heretofore mentioned, must be considered and is due to the different power requirements of different responders. One responder may be provided with only a single code oscillator whereas another responder may include the maximum number p of code oscillators. It is obvious that a response-actuating voltage of a given power level cannot cause radiation of p electromagnetic code responder signals at the same power level as a single electromagnetic code responder signal. Consequently, automatic gain control must take the different power requirements of different responders into account so that curve *b*, Fig. 3, will be the same for all responders.

The advantages attendant with automatic gain control should now become apparent. Receiver 152 can be fully utilized without fear of saturation which otherwise might clip or distort the received responder signals. Also, the magnitude of the coding voltages from rectifiers 160, 162 and 164 will remain constant during the time which corresponds to the flat portion of curve *b*, Fig. 3 and which has been referred to as the selected minimum distance between the responder and the interrogator. In this manner, the reference voltage from sources 180 may be set just a little below the level which corresponds to this flat portion, preventing a coding voltage difference signal except during the time when the automatic gain control is operative, and hence insuring that the register will not be set except under conditions of adequate signal strength.

Automatic gain control, to compensate for the variation in the electromagnetic coupling and the variation of the different power requirements of different responders may be obtained by utilizing an automatic gain control responder signal designated by the frequency f_{agc} and supplied by automatic gain control responder signal oscillator 124. Each responder is provided with a responder oscillator 124 of frequency f_{agc}, which oscillator does not participate in the coding and identification of the responder. A filter 182, which is a band pass filter about the center frequency f_{agc}, and similar in construction to the filters providing the responder signal filter means, is coupled to receiver 152. Consequently, filter 182, will cause the separation of the automatic gain control responder signal from the composite responder signal. The output signal from filter 182, namely the automatic gain control responder signal, may be then applied, if desired, to a rectifier 184 which rectifies the alternating current signal to provide a rectified response voltage. The combination of filter 182 rectifier 184 and receiver 152 thereby provides a rectified response voltage corresponding to a predetermined one of the selected plurality of responder signals.

The output from rectifier 184, the rectified response voltage, may be impressed upon the input circuit of a comparing means such as conventional differential amplifier 186 and compared with a reference voltage of selected magnitude from an adjustable voltage source 188. If the reference voltage exceeds the rectified response voltage, no signal appears on lead 108, and variable gain device 106 inserts minimum attenuation between oscillator 104 and amplifier 110. When the rectified response voltage exceeds the reference voltage, a control signal is obtained, referred to as the automatic gain control difference voltage, which increases the attenuation of variable gain device 110. Such attenuation provides amplitude control of the interrogator signal and indirectly controls the amplitude of each responder signal transmitted from responder 102 to interrogator 100. The combination of differential amplifier 186 and source 188 thereby provides a further comparing means responsive to the rectified response voltage for comparing the magnitude of the rectified response voltage with the reference voltage and operative to derive the automatic gain control difference voltage.

As is easily seen, the level of the reference voltage from source 188 determines how soon, during the approach of interrogator 100 to responder 102, the automatic gain control becomes operative and how soon, as the interrogator 100 and responder 102 move in opposite directions, the automatic gain control becomes inoperative. In other words, the level of the reference voltage determines the length of the time interval during which the interrogator 100 and the responder 102 are cooperating with one another. The term "cooperating" as here used designates the time during which the binary stages of register 172 may be set. Of course, curve *b*, Fig. 3, determines the level of reference voltage from source 180 which controls the minimum power level at which readings might be set into the register 172.

As previously mentioned, the coding voltage difference signals from differential amplifiers 174, 176 and 178 set register 172 by recording either the presence or the absence of a particular code responder signal. It is therefore necessary that register 172 be "clear" prior to the setting of the binary stages thereof. In other words, when interrogator 100 and responder 102 approach one another, no record of a previous recorded binary number should be present on the stages of register 172. For this purpose, an electrical clearing pulse may be applied to each of the stages of register 172 via bus 190 just prior to the time at which interrogator 100 and responder 102 are cooperating with one another. This clearing pulse may be derived from the output of a register clearing means such as a conventional monostable multivibrator 192 which provides a pulse upon being triggered by some control voltage. One suitable control voltage may be derived by utilizing the automatic gain control difference

voltage as shown in Fig. 1. Of course, any signal commensurate with the rectified response signal is suitable. If the automatic gain control difference voltage is utilized, the clearing of code register 172 may take place when the automatic gain control becomes operative, which corresponds to the time at which interrogator 100 and responder 102 are coming into the desired proximity for identification.

It has been found that the reliability of the interrogator receiver means may be still further increased by including a gating means, such as an analog radio or audio frequency gate circuit 194, between receiver 152 and filters 154, 156 and 158. Gate 194 may comprise any one of a number of well known networks which change its state of conduction during the receipt of a pulse of predetermined polarity and duration. The function of gate 194 is to restrict conduction from receiver 152 to the individual stages of register 172 to the time interval when interrogator 100 and responder 102 are at or beyond a selected minimum distance from one another. Gate 194 may be controlled by a control voltage appearing on lead 196 which may be, but need not necessarily be, derived from monostable multivibrator 192. The control voltage for gate 194 appearing on lead 196 may be referred to as the gate actuating signal and preferably takes the shape of a pulse whose duration is about the same as the time interval during which the automatic gain control is operative and coincides therewith. In this manner a gating means is provided which is responsive to a gate actuated signal and operative to transmit the composite code responder signal during the time corresponding to the selected minimum distance. Of course, it is necessary that filter 182 be coupled directly to the receiver, ahead of gate 194, so that the automatic gain control is always operative.

In the interrogator 100 described hereabove, differential amplifier 186 has been utilized to provide automatic gain control and to fire multivibrator 192. It is to be understood, however, that such dual function arrangement has been shown only to retain simplicity of description and that separate amplifiers or separate trigger signal sources may be employed. Likewise, multivibrator 192 has been described as being suitable to simultaneously provide the clearing pulse to register 172 and the gate actuating signal for gate 194. As will be obvious to those skilled in the art, there may be certain advantages in utilizing separate multivibrators or perhaps other kinds of triggers to provide the desired control signals.

Additionally, suitable delay networks may be incorporated in the various control means ot obtain desired sequencing between the operation of the automatic gain control. the gating of the composite electrical responder signal and the clearing pulse. For example it may be desirable to fire multivibrator 192 ahead of full automatic gain control operation to clear the register prior to receiving the gate controlled responder signals. In this connection, the gate actuating signal may also be somewhat delayed with respect to the clearing pulse.

The description of Fig. 1 hereinabove has been explanatory of one embodiment of the signalling system in accordance with this invention, whereby a binary code is set into a code register 172 when interrogator 100 and responder 102 are at a selected minimum distance from each other. When interrogator 100 is mounted upon a railroad vehicle and responder 102 is fixed upon the tracks of the railroad network, the usefulness and versatility of the apparatus of this invention can be extended by providing a data link to transmit the binary code of register 172 to some centrally located agency so that the agency may be apprised at all times of the location of the railroad vehicle. Any number of well known data link systems may be employed for this purpose as is well known to those skilled in the art.

Referring now to Fig. 2*a*, there is shown one illustrative embodiment of a responder constructed in accordance with this invention. A pick-up means such as tuned circuit 200 comprises an inductor L–1 and a capacitor C–1 and provides the receiving element for the electromagnetic interrogator signal. The impedance values of inductor L–1 and capacitor C–1 are selected that tuned circuit 200 is resonant at the frequency of the interrogator signal. Tuned circuit 200 may be selected as a suitable embodiment of pick-up coil 120, Fig. 1, either with or without an additional antenna element, depending upon the specific application of the invention, as is well known to those skilled in the art. In this manner, tuned circuit 200 or a combination of the tuned circuit and an antenna element will provide a pick-up means responsive to electromagnetic radiation in the form of a radio frequency interrogator signal.

A rectifying means such as the combination of diode X–1 and smoothing filter capacitor C–2 may be coupled to tuned circuit 200 to derive the response-actuating voltage from the received interrogator signal. It is, of course, obvious that capacitor C–2 may be replaced by any of many well-known smoothing filters which in conjunction with diode X–1 provides a smooth direct output voltage. The combination of diode X–1 and capacitor C–2 provides the rectifier means shown as block 122 in Fig. 1. The voltage appearing between leads 202 and 204 is the response-actuating voltage.

Even though the responder constructed according to a preferred embodiment of this invention utilizes a rectifier to derive a direct current response-actuating voltage, it is possible to provide a responder which utilizes an alternating current response-actuating voltage to power the responder oscillator.

The remainder of the responder of Fig. 2*a* comprises a plurality of responder signal oscillators of which three are shown and respectively designated by reference characters 210, 212 and 214. The responder signal oscillators are coupled in parallel across leads 202 and 204, which provide the sole power to the oscillators. Oscillator 210 comprises a tank circuit including inductor L–2 and capacitor C–3 whose impedances are selected to provide resonance at the frequency f_{agc}. Oscillator 210 therefore is the automatic gain control responder signal oscillator which provides the automatic gain control responder signal. If a plurality of responders are utilized in a signalling system, each responder preferably includes an oscillator identical to oscillator 210 to derive identical signals for automatic gain control purposes.

Oscillator 210, in addition to the tank circuit designated by the resonance frequency f_{agc} also includes a NPN or PNP transistor X–2 whose collector electrode is coupled to one terminal of tank circuit f_{agc}. The other terminal of tank circuit f_{agc} is coupled to one terminal of inductor L–3 and to lead 202. A parallel combination of resistor R–1 and capacitor C–4 is coupled between the other terminal of inductor L–3 and the base electrode of transistor X–1. Finally the emitter electrode is connected to lead 204. The circuit hereabove described is a transistorized version of the Hartley-type oscillator and is merely explanatory. Numerous different oscillators may be substituted therefor, as for example, those shown in chamber 14 of "Handbook of Semiconductor Electronics," Hunter, 1st edition, 1956, McGraw-Hill, New York.

Code oscillators 212 and 214 may be similar in construction to oscillator 210 described hereabove, except that each has a different resonance frequency as indicated by the f symbol in its tank circuit. Both oscillators 212 and 214 are code responder signal oscillators and provide code responder signals. The maximum number of code responder signal oscillators is designated as p as described in connection with the responder signal filter means. The responder illustrated in Fig. 2*a* provides code responder signals having frequencies f_3 and f_7. Fig. 2*b* illustrates the binary code which this responder would

set into register 172, Fig. 1, if within the selected minimum distance of the interrogator. Responder signals f_3 and f_i therefore provide the selected plurality of code responder signals for the responder of Fig. 2a.

A tuned circuit comprising inductor C-3 and capacitor L-2 may be utilized as the associated responder transmit coil, so that no auxiliary transmit coil is required. Of course, an antenna may be coupled to the tank circuit of the individual responder oscillator to provide the actual radiation element, if so desired. As only a single responder signal is radiated by each of the tank circuits, each of said circuits may be tuned sharply to provide a high gain and a resulting saving of power. Additionally, a high gain circuit will prevent intercoupling of the various tank circuits of the responder signal oscillator means if the frequency separation between the responder signals is kept small. That a small frequency separation is desirable is self evident because broadly tuned interrogator pick-up coil 150, Fig. 1, is the receiving element for all responder signals. The frequency band which may be utilized for the responder signals is therefore determined, at least to some extent, by the interrogator pick-up coil. The narrower the frequency band, the greater will be the power efficiency. Also, the greater the number of different responder signals that may be utilized, the greater the number of responders which may be uniquely identified. Consequently, if a large number of responders are to be employed in a system and the power efficiency is to be kept high, the frequency separation between adjacent responder signals must be kept at a minimum which is only possible by utilizing sharply tuned tank circuits.

The choice of frequencies for the various electromagnetic signals to be utilized with the signalling system of this invention is almost limitless. Some factors which determine a particular selection of frequencies are that as little intercoupling as possible between the various signal is desired. For instance, if the interrogator signal has been selected at the frequency of 120 kilocycles per second, it is good practice to utilize a center frequency for all the responder signals which is different enough not to couple to pick-up coil 120. For example, a responder signal center frequency of 70 kilocycles per second would provide the desired isolation. Additionally the various responder frequencies should not be harmonically related to one another and further have a frequency separation sufficient to prevent undesirable intercoupling between the various responder transmit coils. If 10 code responder signals and one automatic gain control responder signal are desired the following is a typical selection of responder signals: the automatic gain control responder signal may be selected as 70 kilocycles per second and the various code responder signals as 68.9, 67.8, 66.7, 65.6, 64.5, 71.1, 72.2, 73.3, 74.4, 75.5 in kilocycles per second. To provide a composite responder signal comprising a selected number of the code responder signals of identical amplitude, it has been found convenient to adjust the components of the individual responder oscillator to compensate for the slightly different power receive pattern of broadly tuned interrogator pick-up coil 150. Of course, an adjustable attenuator may be placed in series with each of the responder oscillators if so desired.

A number of well known circuits are available in the prior art to provide the elements shown in block form in the drawings. For example, the Jones application, Serial Number 715,899, discloses exemplary circuits for register 172, multivibrator 192 and variable gain device 106 which may be used.

There has been described a signalling system wherein an interrogator in relative motion with a plurality of responders identifies each responder by a binary code. The identification is accomplished by interrogating each response block, at a time when within a selected minimum distance from the interrogator, by means of an electromagnetic interrogator signal having a single frequency. Upon receiving the interrogator signal and in response thereto, the responder provides a selected plurality of responder signals characteristic of a particular responder. The interrogator picks up the selected plurality of response signals and decodes the same to derive a binary code which provides information of the selected plurality of responder signals received. The selected responder signals uniquely identify the particular responder and by knowing either the location of the interrogator or the responder, the location of the other is obtained.

What is claimed is:

1. A passive responder comprising: pick-up means for receiving a radio frequency interrogator signal; rectifying means responsive to said received interrogator signal and operative to develop a response-acting voltage; and oscillator means responsive to said response-actuating voltage and operative to develop and radiate a selected plurality of responder signals of different frequencies simultaneously.

2. A passive responder comprising: a parallel inductance-capacitance tuned circuit for receiving a radio frequency interrogator signal, said circuit being resonant at the frequency of said interrogator signal; rectifying means coupled across said tuned circuit and operative to develop a response-actuating voltage whenever said tuned circuit receives said interrogator signal; and oscillator means responsive to said response-actuating voltage and operative to develop and radiate a selected plurality of responder signals of different frequencies simultaneously.

3. A passive responder comprising: pick-up means responsive to electromagnetic radiation in the form of a radio frequency interrogator signal; rectifying means coupled to said pick-up means to develop a response-actuating voltage commensurate with said interrogator signal; and a plurality of oscillators responsive to and solely powered by said response-actuating voltage, each of said oscillators being operative to radiate simultaneously an electromagnetic responder signal having a different selected frequency.

4. A passive responder comprising: receiver means response to electromagnetic radiation in the form of a radio frequency interrogator signal and operative to develop a direct current voltage; and a selected plurality of radio frequency oscillators coupled to said receiver means and powered solely by said direct current voltage, each of said oscillators operative to develop and radiate an electromagnetic responder signal having a different selected frequency.

5. A passive responder for receiving electromagnetic radiation in the form of an interrogator signal and for radiating in response thereto electromagnetic radiation in the form of a selected plurality of responder signals, said responder comprising: a parallel-resonant inductance-capacitance tuned circuit having a resonance frequency corresponding to said interrogator signal; a rectifying means coupled to said tuned circuit and operative to derive a response-actuating voltage from said tuned circuit when said tuned circuit is excited to resonance; and a plurality of oscillators means, each one of said oscillators means being responsive to said response-actuating voltage and operative to develop one of said selected plurality of responder signals, each of said oscillator means including a further parallel-resonant inductance-capacitance tuned circuit having a resonance frequency corresponding to the associated responder signal and being operative to radiate said associated responder signal.

6. A signalling system for identifying a plurality of passive responders by means of an interrogator capable of relative motion with respect thereto, each one of said plurality of responders being identified when said interrogator is approximately a selected minimum distance therefrom, said signalling system comprising: a plurality of responders, each responder being responsive to the same electromagnetic interrogator signal and each responder being operative to provide in response thereto a different selected plurality of electromagnetic responder

signals; and an interrogator for developing and radiating said electromagnetic interrogator signal and operative to receive each of said different selected pluralities of electromagnetic responder signals, said interrogator being further operative to develop an output quanitity for each one of the responder signals included within the selected plurality of responder signals from a particular responder when said interrogator is within said selected minimum distance from said particular responder.

7. A signalling system for identifying at least one passive responder by means of an interrogator capable of relative motion with respect thereto, said signalling system comprising: an interrogator including a transmitter means for developing and radiating electromagnetic radiation in the form of an interrogator signal, and further including a receiver means responsive to electromagnetic radiation in the form of a selected plurality of responder signals and operative to develop an output quantity for each one of said selected plurality of responder signals; and at least one responder including a pick-up means responsive to said electromagnetic radiation from said transmitter means and operative to develop a response-actuating voltage commensurate therewith, and further including an oscillator means responsive to said response-actuating voltage and operative to develop and radiate said electromagnetic radiation in the form of said selected plurality of responder signals, said responder being powered solely by the electromagnetic radiation from said transmitter means.

8. A signalling system according to claim 7 wherein said interrogator transmitter means comprises: an interrogator signal source means for developing said interrogator signal, amplifier means coupled to said interrogator means for suitably amplifying said interrogator signal, and an interrogator transmit coil responsive to said amplified interrogator signal and operative to radiate said interrogator signal as electromagnetic radiation.

9. A signalling system according to claim 8 wherein said interrogator transmit coil comprises a tuned circuit resonant at the frequency of said interrogator signal.

10. A signalling system according to claim 7 wherein said interrogator receiver means comprises: an interrogator pick-up means for developing a composite responder signal from said received electromagnetic radition, amplifying means responsive to said composite responder signal and operative to provide an amplified composite responder signal, responder signal filter means responsive to said amplified composite responder signal and operative to derive a separate coding signal for each of said selected plurality of responder signals, and code register means responsive to each one of said coding signals and operative to derive said output quantity for each one of said selected plurality of responder signals.

11. A signalling system according to claim 10 wherein said code register means includes a register having a plurality of binary stages, each binary stage being associated with a different responder signal, said stage being responsive to the rectified components of said coding signals.

12. A signalling system according to claim 10 wherein said interrogator pick-up means comprises a broadly tuned circuit substantially at resonance at each one of the frequencies of said responder signals.

13. An interrogator-responder system comprising: interrogator transmitter means for transmitting electromagnetic radiation in the form of a single frequency interrogator signal; a passive responder responsive to said interrogator signal and operable to provide electromagnetic radiation in the form of a selected plurality of responder signals differing from one another in frequency, said interrogator transmitter means and said responder being capable of relative motion with respect to one another; interrogator receiver means associated with said interrogator transmitter means and responsive to said selected plurality of responder signals and operative to develop a composite responder signal; responder signal filter means responsive to said composite electrical responder signal and operative to derive a separate coding signal for each one of said selected plurality of responder signals; detector means responsive to each of said coding signals and operative to develop coding voltages; and register means having a different binary stage associated with each responder signal for indicating each one of said selected plurality of responder signals received by said receiver means, each stage being responsive to an associated coding voltage.

14. An interrogator-responder system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for transmitting amplitude controlled electromagnetic radiation in the form of a single frequency interrogator signal; a passive responder responsive to said interrogator signal and operable to provide in response thereto electromagnetic radiation in the form of a selected plurality of responder signals differing from one another in frequency, said interrogator transmitter means and said responder being capable of relative motion with respect to one another so as to vary the electromagnetic coupling therebetween; interrogator receiver means associated with said interrogator transmit means and responsive to said selected plurality of responder signals and operative to develop a composite responder signal and a rectified response voltage corresponding to a predetermined one of said selected plurality of responder signals; comparing means responsive to said rectified response voltage for comparing the magnitude of said rectified responsive voltage with a reference voltage and operative to derive said automatic gain control difference voltage; responder signal filter means responsive to said composite responder signal and operative to derive a separate coding signal for each one of said selected plurality of responder signals; detector means responsive to each of said coding signals and operative to develop coding voltages; and register means having a different binary stage associated with each responder signal for indicating each one of said selected plurality of responder signals received by said receiver means, each stage being responsive to an associated coding voltage.

15. An interrogator-responder system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for transmitting amplitude controlled electromagnetic radiation in the form of a single frequency interrogator signal; a passive responder responsive to said interrogator signal and operable to provide in response thereto electromagnetic radiation in the form of a selected plurality of responder signals differing from one another in frequency, said interrogator transmitter means and said responder being capable of relative motion with respect to one another; interrogator receiver means associated with said interrogator transmitter means and responsive to said selected plurality of responder signals and operative to develop a composite responder signal and a rectified response voltage corresponding to a predetermined one of said selected plurality of responder signals; first comparing means responsive to said rectified response voltage for comparing the magnitude of said rectified responsive voltage with a first reference voltage and operative to derive said automatic gain control difference voltage; responder signal filter means responsive to said composite responder signal and operative to derive a separate coding signal for each responder signal included within said composite responder signal; detector means responsive to each of said coding signals and operative to develop coding voltages; second comparing means responsive to each of said coding voltages for comparing the magnitude of each of said coding voltages with a second reference voltage and operative to derive coding voltage difference signals; and register means having a different binary stage associated with each responder

signal for indicating said selected plurality of responder signals received by said receiver means, each stage being responsive to an associated coding voltage difference signal.

16. An interrogator responder system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for transmitting amplitude controlled electromagnetic radiation in the form of a single frequency interrogator signal; a passive responder responsive to said interrogator signal and operable to provide electromagnetic radiation in the form of a selected plurality of responder signals differing from one another in frequency, said interrogator transmitter means and said responder being capable of relative motion with respect to one another; interrogator receiver means associated with said interrogator transmitter means and responsive to said selected plurality of responder signals and operative to develop a composite responder signal and a rectified response voltage corresponding to a predetermined one of said selected plurality of responder signals; first comparing means responsive to said rectified response voltage for comparing the magnitude of said rectified response voltage with a first reference voltage and operative to derive said automatic gain control difference voltage and a gate actuating signal when said responder and said interrogator transmitter means are at a selected minimum distance from one another; gating means coupled to said receiver means and responsive to said gate actuating signal and operative to transmit said composite electrical responder signal during the time corresponding to said selected minimum distance; responder signal filter means responsive to said gated composite responder signal and operative to derive separate coding signals for each one of said responder signals included within said composite responder signal; detector means responsive to each of said coding signals and operative to develop coding voltages; second comparing means responsive to each of said coding voltages for comparing the magnitude of each of said coding voltages with a second reference voltage and operative to derive coding voltage difference signals; register means having a different binary stage associated with each responder signal for indicating said selected plurality of responder signals received by said receiver means, each stage being responsive to an associated coding voltage difference signal and a reset control signal; and register clearing means responsive to a voltage derived from said rectified response voltage and operative to provide said reset control signal.

17. A signalling system for identifying at least one passive responder with respect thereto, said signalling system comprising: interrogator transmitter means for generating and radiating an electromagnetic interrogator signal of a single frequency; at least one responder pick-up means electromagnetically coupled to said interrogator transmitter means and responsive to said electromagnetic interrogator signal, said electromagnetic coupling increasing as the distance between interrogator and said responder decreases; responder rectifying means coupled to said responder pick-up means and operative to develop a response-actuating voltage corresponding to said electromagnetic interrogator signal; responder oscillator means responsive to said response-actuating voltage and operative to generate and radiate simultaneously a selected plurality of electromagnetic responder signals differing from one another in frequency, each responder having a different responder oscillator means to provide a different selected plurality of electromagnetic responder signals for identifying a responder uniquely; and interrogator receiver means associated with said interrogator transmitter means and responsive to said electromagnetic responder signals, said interrogator receiver means being operative to develop a distinct output quantity for each responder signal in said selected plurality of electromagnetic responder signals.

18. A signalling system for identifying at least one passive responder by means of an interrogator in relative motion with respect thereto, each of said responder being identified when said interrogator is approximately at a selected minimum distance therefrom, said signalling system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for generating and transmitting an amplitude controlled electromagnetic interrogator signal of a single frequency; at least one responder pick-up means electromagnetically coupled to said interrogator transmitter means and responsive to said interrogator signal, said electromagnetic coupling increasing as the distance between said interrogator and said responder decreases; responder rectifying means coupled to said responder pick-up means and operative to develop a response-actuating voltage corresponding to said electromagnetic interrogator signal; responder oscillator means responsive to said response-actuating voltage and operative to generate and radiate simultaneously a plurality of electromagnetic responder signals differing from another in frequency, said plurality of responder signals comprising an automatic gain control responder signal and a selected plurality of code responder signals, each responder having a different responder oscillator means to provide a different selected plurality of code responder signals which identify a responder uniquely; interrogator receiver means associated with said interrogator transmitter means and responsive to said electromagnetic responder signals, said interrogator receiver means being operative to develop an automatic gain control voltage corresponding to the received power level of said automatic gain control responder signal and a distinct output quantity for each of said code responder signals in said selected plurality of electromagnetic responder signals; and comparing means responsive to said automatic gain control voltage for comparing the magnitude of said automatic gain control voltage with a reference voltage and operative to derive said automatic gain control difference voltage.

19. A signalling system for identifying a plurality of passive responders by means of an interrogator capable of relative motion with respect thereto, each of said responders being identified when said interrogator is approximately at a selected minimum distance therefrom, said signalling system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for generating and transmitting an amplitude controlled electromagnetic interrogator signal of a single frequency; a plurality of responder pick-up means, each responder pick-up means being capable of electromagnetically coupled to said interrogator transmitter means and responsive to said interrogator signal, said electromagnetic coupling increasing as the distance between said interrogator and said responder decreases; a responder rectifying means coupled to each of said responder pick-up means, said responder rectifying means being operative to develop a response-actuating voltage corresponding to said electromagnetic interrogator signal; responder oscillator means responsive to said response-actuating voltage and operative to generate and radiate simultaneously a plurality of electromagnetic responder signals differing from another in frequency, said plurality of responder signals comprising an automatic gain control responder signal and a selected plurality of code responder signals, each responder having a different responder oscillator means to provide a different selected plurality of code responder signals which identify a responder uniquely; interrogator receiver means associated with said interrogator transmitter means and responsive to said electromagnetic responder signals, said interrogator receiver means being operative to develop an automatic gain control voltage corresponding to the received power level of said automatic gain control responder signal and a distinct output quantity for each of

said code responder signals in said selected plurality of electromagnetic responder signals, said receiver means also including gating means responsive to a gate actuating signal for preventing the developing of said output quantities unless said interrogator is within said selected minimum distance from a responder; first comparing means responsive to said automatic gain control voltage for comparing the magnitude of said automatic gain control voltage with a first reference voltage and operative to derive said automatic gain control difference voltage; second comparing means responsive to said automatic gain control voltage for comparing the magnitude of said automatic gain control voltage with a second reference voltage and operative to derive said gate actuating signal, the level of said second reference voltage being selected to actuate said gate during said selected minimum distance.

20. An interrogator-responder system comprising: interrogator transmitter means including automatic gain control means responsive to an automatic gain control difference voltage for transmitting amplitude controlled electromagnetic radiation in the form of a single frequency interrogator signal; a passive responder responsive to said interrogator signal and operable to provide in response thereto electromagnetic radiation in the form of a selected plurality of responder signals differing from one another in frequency, said interrogator transmitter means and said responder being capable of relative motion with respect to one another; interrogator receiver means including beat frequency means associated with said interrogator transmitter means and responsive to said selected plurality of responder signals and operative to develop a reduced frequency composite responder signal and a rectified response voltage corresponding to a predetermined one of said selected plurality of responder signals; first comparing means responsive to said rectified response voltage for comparing the magnitude of said rectified responsive voltage with a first reference voltage and operative to derive said automatic gain control difference voltage; responder signal filter means responsive to said reduced frequency composite responder signal and operative to derive a separate coding signal for each responder signal included within said composite responder signal; detector means responsive to each of said coding signals and operative to develop coding voltages; second comparing means responsive to each of said coding voltages for comparing the magnitude of each of said coding voltages with a second reference voltage and operative to derive coding voltage difference signals; and register means having a different binary stage associated with each responder signal for indicating said selected plurality of responder signals received by said receiver means, each stage being responsive to an associated coding voltage difference signal.

No references cited.